HOS-85-02

Noise Emission Levels for Vehicles in Ontario

F.W. Jung

C.T. Blaney

A.L. Kazakov

Ontario

Ministry of
Transportation and
Communications

Research and
Development
Branch

86-04023/

Technical Report Documentation Page

MTC Report Number	ISBN Number	Other Document Number	Date
HOS-85-02			Nov/85

Title: Noise Emission Levels for Vehicles in Ontario

Author: F.W. Jung, Senior Research Engineer
C.T. Blaney, Research Technician
A.L. Kazakov, Research Officer

Published by:
Research and Development Branch
Ontario Ministry of Transportation and Communications

Client Group:

Participating Agencies:

Abstract: The FHWA traffic noise prediction model(STAMINA) has been adopted in Ontario because of its flexibility and analytical features which accomodate changed conditions through simple updating procedures. Major inputs for STAMINA are the reference energy mean emission levels of vehicle classes as a function of speed. These functions were established by the FHWA in their original report, based on the data collected in the U.S. before 1978. However, conditions in 1985, in Ontario, are different, and the noise emission level functions used in the STAMINA and other related programs should be re-evaluated.

Data on reference emission levels of cars, medium and heavy trucks were collected during 1984 and 1985, processed and statistically analysed. From these data, functions of reference noise emission levels with vehicle speed were established for those vehicle groups. These functions can be used in programs derived from the FHWA model.

The findings in Ontario confirm those in other jurisdictions in the U.S., namely that heavy trucks emit less noise at high speeds than originally indicated by the FHWA model.

Further, it is shown that about 4% of heavy trucks are notoriously noisy compared to the general population and cause an upward shift of the reference emission level function by 0.5 to 1dBA. These noisy trucks are relatively rare events which may or may not be missed in noise measurements of short duration (20 minutes), but they have a high impact on the level of noise pollution.

Key Words: noise emission levels, noise prediction model, STAMINA, FHWA

Comments: Presented at the 65th Annual Meeting of the Transportation Research Board, Washington, D.C.

Distribution: 100 copies TRB, selected researchers

Copyright Status: Crown Copyright

HOS-85-02

Noise Emission Levels for Vehicles in Ontario

F.W. Jung
Senior Research Engineer

C.T. Blaney
Research Technician

A.L. Kazakov
Research Officer

Research and Development Branch

Published by:
The Research & Development Branch
Ontario Ministry of Transportation and Communications
Hon. Ed Fulton, Minister
D.G. Hobbs, Deputy Minister

Published without prejudice
as to the application of the findings.
Crown copyright reserved; however, this
document may be reproduced for non-commercial
purposes with attribution to the Ministry.

For additional copies, contact:
The Editor, Technical Publications
Ministry of Transportation and Communications
1201 Wilson Avenue
Downsview, Ontario
Canada M3M 1J8
(416) 248-7226

November 1985

TABLE OF CONTENTS

Page

1/ INTRODUCTION 1

2/ FIELD MEASUREMENTS 2
2.1/ Test Sites 2
2.2/ Measurement Procedure 3

3/ RESULTS 5

4/ DISCUSSION 6
4.1/ Statistical Problems 6

5/ CONCLUSIONS AND RECOMMENDATIONS 8

REFERENCES 9

TABLES 10

FIGURES 12

1/ INTRODUCTION

Numerous methods have been developed to estimate or predict highway traffic noise, a major source of noise pollution in residential areas. In Ontario, for many years, the standard method of predicting traffic noise adjacent to freeways and highways was that developed by J.J. Hajek [1]. However, his model was empirically-based on numerous field measurements and comprises a mathematical simulation of overall traffic flow noise. Thus, like other empirical models, this method was bound to become outdated as soon as real-world conditions changed. For example, more stringent vehicle emission level standards would reduce noise effectively and invalidate some of the assumptions on which the model was based. Reformulation of such empirical models is rather difficult because one must resort to repetition of numerous field measurements.

In 1977 the U.S. Federal Highway Administration (FHWA) developed an analytical model for traffic noise prediction, based on and built up from basic principles of acoustics [2]. Such a model can easily be calibrated for new conditions because reference noise emission levels from various classes of vehicles are used as separate independent inputs. Once mean values of these levels are established, the total noise from overall traffic flow is then calculated from the amount and composition of traffic as it exists or is projected for a particular highway. When the FHWA model was published, certain reference noise emission levels were recommended and spelled out as functions of speed and vehicle type. At the same time, however, it was recommended that each agency (state or province) should carry out its own investigations of noise emission levels of the prevailing classes of vehicles, taking into account regional conditions such as composition and design of truck or automobile populations, enforcement and compliance with regulations and standards. Furthermore, such conditions may change significantly in the course of time, so that collection and processing of vehicle noise data should be repeated periodically (i.e., every 5 or 10 years).

In other words, once sufficient emission level data have been collected, the analytical character of the FHWA model allows for a relatively simple update of prediction calculations, as described and reported below.

In 1984 the State of Georgia reported [4], based on a relatively small sample of measurements, that heavy and medium trucks were emitting less noise at higher speeds than predicted by the FHWA model [1,2,5]. In other words, the FHWA model was overestimating noise levels for travelling near the legal speed limit (80 to 100 km/h).

In 1985, a California report [6] based on a much larger sample of measurements showed similar findings -- trucks at higher speeds are less noisy.

The analytical traffic noise prediction model of the FHWA was introduced in Ontario in 1982 and was finally adopted more for its flexibility than for its superior accuracy. Using the original FHWA emission level functions, the model revealed a tendency for slight overprediction of noise along expressways when predicted and measured values were compared. Thus, it was decided to carry out a specific Ontario study on noise emission levels of vehicles.

The primary objective of the study was to develop and establish up-to-date vehicle noise reference energy mean emission levels for Ontario, as required and defined by the FHWA prediction model [2,6]. These reference noise levels are also needed for simplified prediction methods that have been developed from the original FHWA model to serve the less sophisticated needs of persons such as environmental planners [7,8].

2/ FIELD MEASUREMENTS

2.1/ Test Sites

The basic requirements of a test site are shown in Figures 1a and 1b. The sites chosen for inclusion in the Ontario survey are shown in Figure 4. A map showing the location of these sites is also presented in Figure 4. The sound level measurement sites are spread over a wide cross section of the Ontario road system.

It was necessary to test a number of sites in order to include representative variation in pavement type, ground condition, vehicle type and vehicle speed. All sites were located in an open level area free of obstructions such as parked cars, buildings or sign boards, and all had low background sound levels more than 10 dBA below the lowest measured levels. Further, as a result of an investigation at the airport site with vehicles travelling on the runways, it was found to be very important to conduct measurements when the wind speed does not exceed a limit of approximately 20 km/h.

The microphones at all sites were located 15 m from the centre of the travelled lane and 1.2 m above pavement elevation. A clear line of site was maintained between the microphone position and the roadway in both directions. All pavements were in fair to good condition. In short, measurements were carried out in accordance with the general requirements given in [9].

All measurement sites were at rural or quiet urban locations with low traffic volumes in order to measure passing vehicles independently, as single events.

2.2/ Measurement Procedure

Prior to undertaking field measurements, the instruments were checked in the laboratory to ensure proper calibration. The instruments used in this procedure were as follows:

- Bruel & Kjaer Noise Level Analyser, Type 4426
- Bruel & Kjaer Sound Level Meter, Type 2218
- Bruel & Kjaer Calibrator, Type 4230
- Bruel & Kjaer Alphanumeric Printer, Type 2312
- Bruel & Kjaer Graphic Level Recorder, Type 2306
- Bruel & Kjaer 1/2 inch Microphone, Type 4165
- Bruel & Kjaer 30 m Microphone Extension Cable, Type AO 0029
- Bruel & Kjaer Microphone Windscreen
- Uher Tape Recorder, Type 4200 Report Monitor
- Tripod

Note: All of the sound level meters comply with the requirements of Type 1 Precision instruments as per ANSI S1.4, 1983 [10]

Two sound level measurement systems were set up and calibrated on-site with microphones placed at the same location, 15 m from the highway. The main reason for using two independent measuring systems is that one system can act as a check on the other thus avoiding the possibility of introducing any gross errors in the measured sound levels. After initial calibration, a 10 minute comparison test of the performance of the sound measuring instruments using the noise emitted from the traffic on the nearby highway was done. The measuring systems were re-calibrated approximately once every hour or sooner when necessary (for example, when batteries had to be changed in an instrument). The two measuring systems were comprised as follows.

System One consisted of a microphone and pre-amplifier placed upon the end of a 30 m extension cable and connected to a Bruel & Kjaer 2218 sound level meter. The AC voltage output from this meter was tape recorded on one channel of a stereo tape recorder with the other channel reserved for comments about the vehicle passing by. The sound level meter in this system is not used to read the sound levels as the vehicle passes but only to condition the signal for tape recording. The recorded audio tapes are kept for evaluation at a later date in the laboratory.

System Two comprised a microphone and pre-amplifier placed on a 30 m extension cable and connected to a Bruel & Kjaer 4426 noise level analyser. This system allows for direct field evaluation of the sounds emitted from passing vehicles.

The maximum sound level measured as the vehicle passes is obtained from the noise analyser, System Two. This, as well as the speed and type of vehicle, are recorded on data sheets in the field. The speed of the vehicle is measured by timing it over a 150 m (see Figure 1) distance. These data are later verified from information recorded on the audio tapes of System One.

3/ RESULTS

Data on vehicle noise emission levels were collected at various locations in Ontario, as shown in Figure 4, to obtain a set of pooled vehicle- and speed-related data fairly representative of Ontario conditions. These data were processed in two ways, with respect to groupings or classes of vehicles with similar levels of noise emission.

Firstly, in accordance with the original FHWA report [1], vehicles were assigned to one of three classifications -- heavy trucks (HT), medium weight trucks (MT), and automobiles (A), which includes cars and other vehicles of similar noise emission. An accurate definition of these classes is given in Reference 1, Page 4.

Secondly, vehicles were further classified in accordance with groupings customary in Ontario, namely by dividing them into long trucks (LT), short trucks (ST), and automobiles (A). These vehicles classes were introduced not for accoustical reasons but because traffic data can be more readily obtained in these terms. The Ontario classes are illustrated in Figure 5, and a comparison between the Ontario and FHWA grouping of vehicles is presented in Figure 6.

The measurements were sorted by speed classes (every 5 km/h) as well as by vehicle type, and each group or cluster of measurements was statistically analysed. The results are shown in Table 1 with vehicles being classified according to the FHWA definitions (HT, MT, and A). The sample size for each speed and vehicle class is also shown, together with the mean and standard deviation of noise emission levels. The results for the second grouping by Ontario vehicle classes (LT, ST, and A) are similar, and are therefore not shown in tabular form.

The data shown in Table 1 were subjected to a linear regression analysis in order to obtain the customary expressions for the reference energy mean noise emission levels of each vehicle class. The resulting curves are presented in Figures 7 and 8 for the FHWA and Ontario classes, respectively.

Figure 9 compares the Ontario emission levels with the originally published FHWA levels [1], for heavy (HT) and medium weight (MT) trucks,

and for automobiles (A). The comparison shows that, in Ontario, trucks emit less noise at high speeds. On the other hand, automobiles are noisier, especially at lower speeds. Furthermore, medium weight trucks are somewhat less noisy at higher speeds but slightly noisier at lower speeds. Since speeds of 80 to 100 km/h are legal in Ontario, the aforementioned difference must lead to an overprediction of truck noise when using the original FHWA emission level functions. The difference in car noise at high speeds is less significant.

Figures 10a, b, and c illustrate the statistical variations of the measurements and show average values of emission levels in each speed class and vehicle group. The points of plus/minus one standard deviation (vertically) are also plotted. The vehicle groups used in Figure 10 are those defined by the FHWA. The curves shown are regression lines identical to those in Figure 7.

The resulting equations for the reference energy emission levels as found from the 1984/85 measurements in Ontario are listed in Table 2. This table can be used to provide new, up-to-date input for the various programs based on the FHWA model [1,5,8] when used in Ontario.

The effect of the new equations for Ontario is illustrated by a typical case shown in Figure 11, for vehicles travelling close to the legal speed limit of 100 km/h. This example of an expressway in an urban area consists of three westbound (R1) and three eastbound (R2) lanes. Predictions at 30 m and at 60 m from the near lane centre are compared. In both cases, the original FHWA equations predict noise 1 dBA above the new Ontario equations. For lower speeds the difference will be smaller or will be reversed. For a larger percentage of trucks, at 100 km/h, the difference would be larger than 1 dBA.

4/ DISCUSSION

4.1/ Statistical Problems

Single event noise emission levels of vehicles were measured in terms of dBA. Because dBA is a logrithmic scale, the measured values must be

converted to sound pressure energies before manipulating them. The mean values of each sample in each speed and vehicle class were calculated as follows:

$$L_m = 10 \log \left[\frac{1}{n} \sum_{i=1}^{n} 10^{L_i/10} \right]$$

(1) where: L_i = noise emission level of single event, in dBA

L_m = mean value of sample, average noise emission level, in dBA

n = sample size

This method of calculating average values of noise emission levels is consistent with the definition of L_{eq}.

The normalized distribution of sound pressure energy for the Ontario heavy truck population is shown in Figure 12a. To obtain this distribution, the sample data from all heavy trucks travelling at speeds greater than 80 km/h were normalized to a zero mean value in each speed group and then pooled. The pooling was possible because F-tests showed no statistically significant difference between the standard deviations of the different speed groups. Whereas Figure 12a shows the distribution of sound pressure energy measurements in a non-logarithmic scale, Figure 12b illustrates the same information as normalized noise emission levels in terms of dBA, which is a logarithmic scale.

Both Figures, 12a and b, exhibit a long tail of high noise emission levels. The upper part of the tail, beyond 5 dBA above the mean value, represents only approximately 4% of the truck population, which contribute an additional one- half to 1 dBA to the average emission level of trucks. This represents about 1/5 of the sound pressure energy.

These 4% of unusually noisy trucks are intrusive in their noise impact compared to the general population, and from the shape of the distribution curves one may conclude this may be due to unusual circumstances such as faulty mufflers, etc. More stringent enforcement of regulatory

standards could discourage such high emission levels and would affect only 4% of the truck population.

With regard to the practice of noise measurements, the following should be pointed out. In a small sample size (such as obtained by 20 minutes of measurements on roads of low traffic volume) those very noisy vehicles in the tail of the distribution curves will probably be missed. This would result in a lower average value of noise than would be representative for a 24-hour L_{eq}, the current Ontario standard of noise control. With the increasing sample size the measured average noise emission level would "creep up", due to the increasing probability of encountering those excessively noisy events from the tail of the distribution. Thus, measurements of 20 minutes duration at low traffic volumes may underestimate the 24-hour L_{eq} noise which is used as a standard duration of measurement in Ontario.

5/ CONCLUSIONS AND RECOMMENDATIONS

Functions of reference energy mean emission levels with speed have been established for heavy trucks, medium weight trucks, and automobiles in Ontario. The levels are different from those currently used in the STAMINA program of the FHWA model. In particular, it has been found that

heavy trucks are less noisy at high speeds, near the legal speed limit. Trucks and cars at low speed are noisier.

When using STAMINA or any other noise prediction program derived from the analytical FHWA model, new equations for reference emission levels should be used. For Ontario, those are as listed in Table 2.

Noise emission levels of vehicles should be regulated by establishing a legal maximum noise limit to exclude the rare events in the upper tail of vehicle noise distributions which have a high impact on noise pollution.

REFERENCES

[1] Hajek, J.J. "Ontario Highway Noise Prediction Method," Transportation Research Circular No. 175, TRB, Washington, D.C., Jan. 1976, pp. 59-69.

[2] Barry, T.M. and Reagan, J.A., "FHWA Highway Traffic Noise Prediction Model," US Federal Highway Administration, Report FHWA-RD-77-108, December 1978.

[3] Rickley, E.J., Ford, D.W. and Quinn R.W., "Highway Noise Measurements for Verification of Prediction Models," US Department of Transportation, Report Number DOT-TSC-OST-78-2 and DOT-TSC-FHWA-78-1.

[4] Harris, R.A., "Determination of the Reference Mean Emission Level in Georgia," In Transportation Research Record 983, TRB, National Research Council, Washington, D.C., 1984, pp 22-27.

[5] Rudder, F.F., Lam, D.F., and Chueng, P., "User's Manual: FHWA Level 2 Highway Traffic Noise Prediction Model STAMINA 1.0," U.S. Federal Highway Administration, Report FHWA-RD-78-138, May 1979.

[6] Hendriks, R.W., "California Vehicle Noise Emission Levels," Report Prepared for the January 1985 TRB Meeting.

[7] Hajek, J.J. and Jung, F.W., "Simplified FHWA Noise Prediction Method," Ontario Ministry of Transportation and Communications. Report AE-82-05, July 1982.

[8] Jung, F.W., "Manual Method of Predicting Highway Traffic Noise and Sound Barrier Performance" MTC-R&D Report, AE-81-07, 1981.

[9] Bowlby, W., Editor, "Sound Procedures for Measuring Highway Noise: Final Report," US Federal Highway Administration, Report FHWA-DP-45-1R, August 1981.

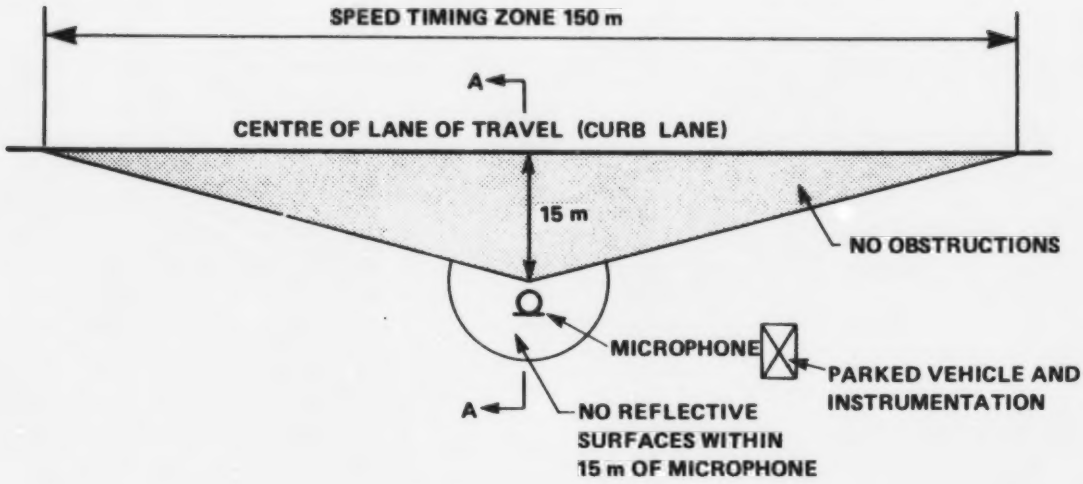
Table 1/ Results of Field Measurements (all sites, pooled)

	Speed Class	Emission Level	Standard Deviation	Sample Size
Heavy Trucks	40	79.2	2.9	15
	50	83.0	3.3	33
	60	82.8	2.4	35
	65	83.9	2.2	34
	70	84.7	2.7	52
	75	85.0	2.7	78
	80	83.9	2.2	106
	85	84.4	2.3	133
	90	84.9	2.4	119
	95	85.7	2.2	122
	100	85.9	2.4	88
	105	86.1	2.5	41
	110	85.9	1.8	29
TOTAL				885
Medium Trucks	50	75.2	4.0	19
	60	79.2	4.3	10
	70	77.7	3.3	15
	75	81.0	3.9	21
	80	80.0	3.5	29
	85	81.4	3.0	25
	90	82.5	3.9	35
	95	82.2	2.9	19
	100	83.0	3.9	15
	105	84.3	3.9	7
TOTAL				195
Cars	50	64.5	2.3	10
	55	65.2	2.1	7
	60	67.9	1.9	13
	65	68.0	1.8	12
	70	70.9	2.2	30
	75	71.8	2.2	55
	80	72.4	2.2	100
	85	73.2	2.1	91
	90	73.0	2.1	138
	95	73.9	2.2	117
	100	73.9	1.5	112
	105	74.7	1.8	52
	110	75.0	1.7	60
	115	75.8	1.9	20
	120	76.7	1.4	6
	130	77.5	1.8	7
TOTAL				830

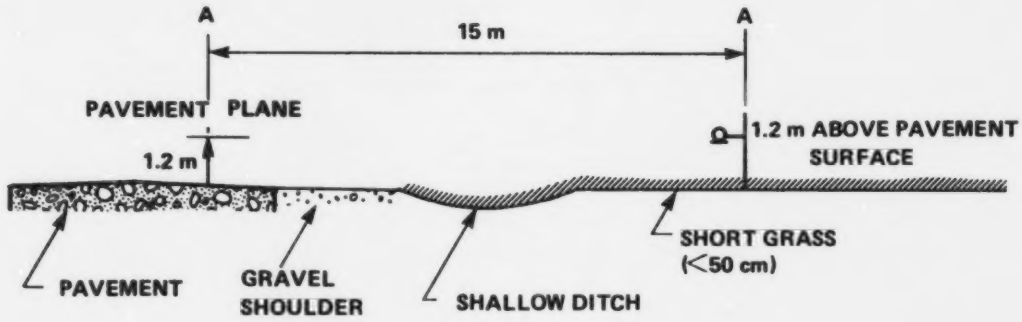
Table 2/ Reference Mean Emission Levels (dBA) in Ontario

Vehicle Class	Equation
Heavy Trucks	12.59 logS + 60.64
Long Trucks	10.88 logS + 63.98
Medium Trucks	24.06 logS + 34.90
Short Trucks	14.60 logS + 54.69
Cars	30.41 logS + 13.59

Note S = speed in km/h



a) TYPICAL SITE LAYOUT



b) TYPICAL SITE CROSS-SECTION A - A

Figure 1/ Typical Layout of Roadside Measurements

Figure 2/ Single Event (Truck) on Highway 402

Figure 3/ View of Typical Site

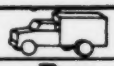
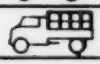
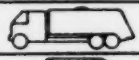
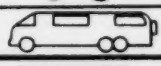
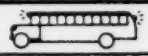
Legend : Description of Locations

1. Hwy. 402, 6 km East of Sarnia
2. Hwy. 402, 29 km East of Sarnia
3. Hwy. 6 near Guelph
4. Hwy. 405 near Queenston
5. Hwy. 420 in Niagara Falls
6. Simcoe County Regional Road 9 west of New Lowell
7. Commissioners Street in downtown Toronto
8. Hwy. 2 West of Prescott
9. Airport North of London (inactive)

Figure 4/ MEASUREMENT LOCATIONS

VEHICLE CLASSIFICATION

(GROUPING OF TRUCK TYPES)

GROUP	SHORT TRUCKS (HEAVY 2&3 AXLE - SINGLE UNITS)	
	HEAVY TRUCK (DUAL REAR TIRES)	
	DUMP TRUCK	
	STAKE TRUCK	
	TRACTOR WITHOUT TRAILER (2 AXLES)	
	SINGLE UNIT TRUCKS WITH 3 AXLES	
	TRACTOR WITHOUT TRAILER (3 AXLES)	
	TANK TRUCK (SINGLE UNIT)	
	VAN (DUAL REAR TIRES)	
	MOTOR HOME	
	SCHOOL BUS	
	REGULAR BUS	

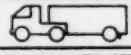
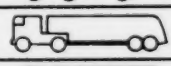
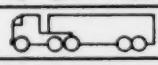
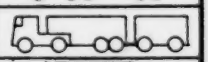
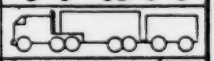
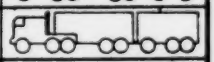
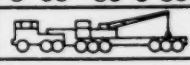
GROUP	LONG TRUCKS (TRANSPORTS - COMBINATION UNITS)	
	COMBINATION UNIT (3 AXLES)	
	COMBINATION UNIT (4 AXLES)	
	COMBINATION UNIT (5 AXLES)	
	COMBINATION UNIT (6 AXLES)	
	COMBINATION UNIT (7 AXLES)	
	COMBINATION UNIT (8 AXLES)	
	COMBINATION UNIT (9 AXLES)	

Figure 5/ Short Truck/Long Truck Classification in Ontario

	MTC SHORT TRUCKS SINGLE UNITS		MTC LONG TRUCKS COMBINATION UNITS
	MEDIUM TRUCKS	HEAVY TRUCKS	
AXLES	2 AXLES - 2 TIRES ON REAR AXLE	2, 3 & 4 AXLES - 4 TIRES ON REAR AXLE/S	3 OR MORE AXLES TRANSPORTS
WEIGHT	GENERALLY LESS THAN 5 500 kg	MAX. 38 300 kg	MAX. 63 500 kg
LENGTH		MAX. 12.5 m	MAX. 21 m
BODY STYLES	VANS, PICKUP	DUMP, STAKE, TANKER, BOX, TOW TRUCK	TRACTOR TRAILERS, FLATBED, TANKER TRAILERS, CAR CARRIERS

Figure 6/ Comparison of Classifications, Ontario/FHWA

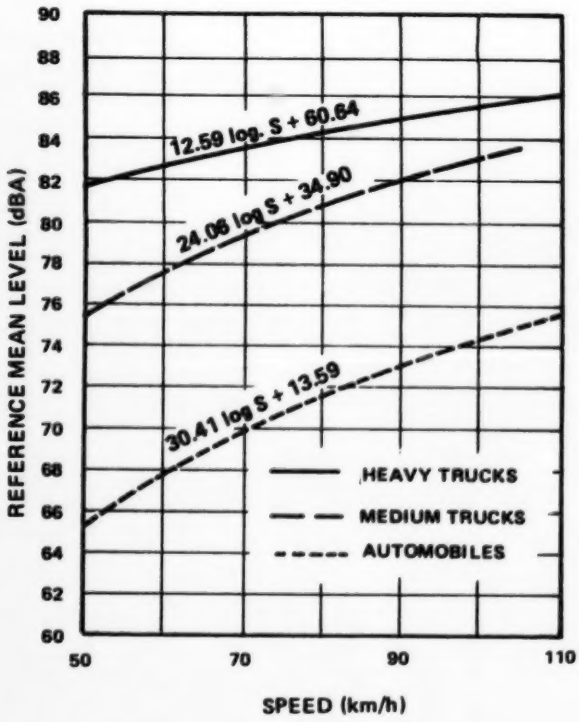


Figure 7/ Emission Levels of Ontario Vehicles Classified According to FHWA

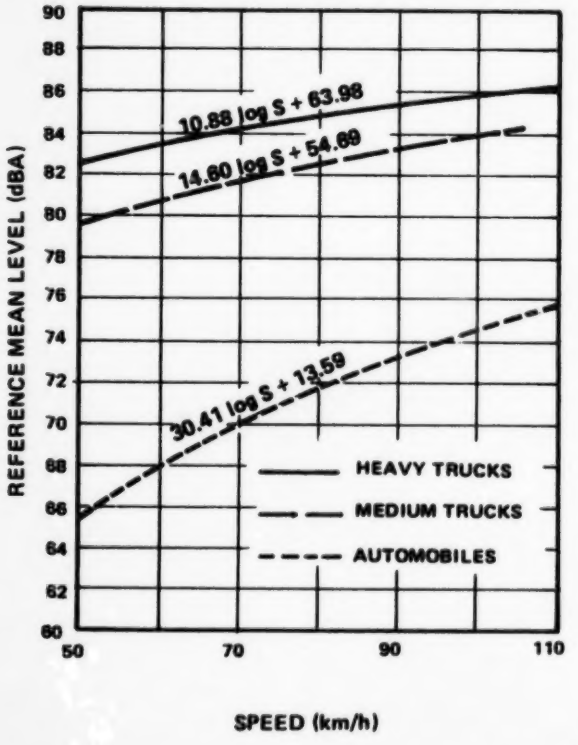


Figure 8/ Emission Levels of Ontario Vehicles Classified According to Short Truck/Long Truck

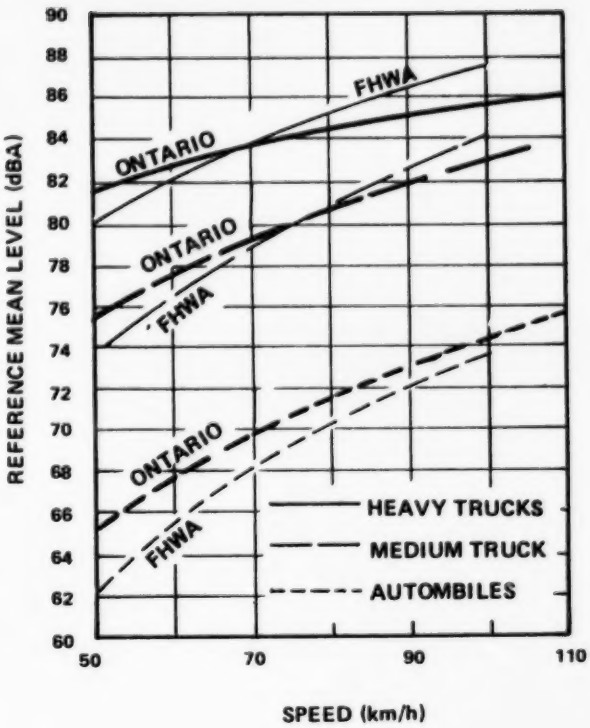
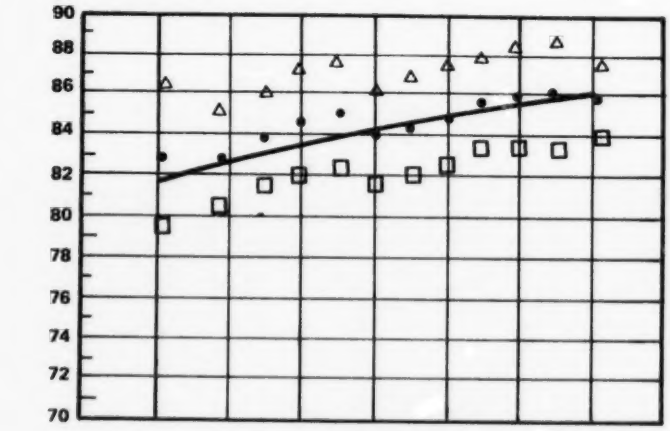
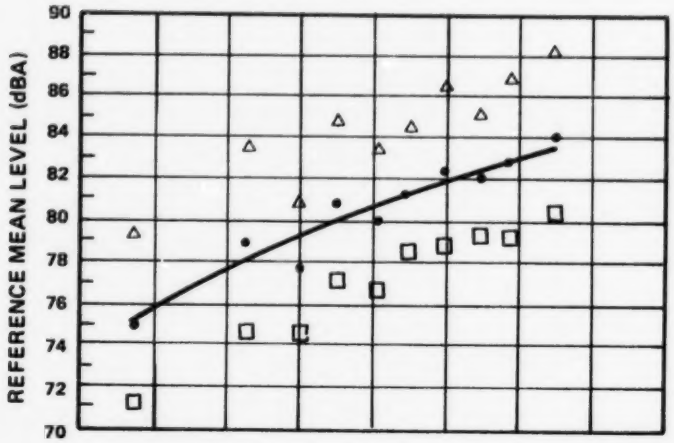


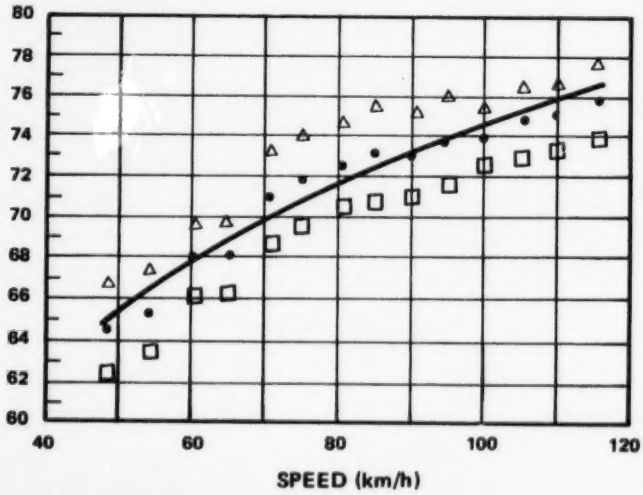
Figure 9/ Comparison of Figure 7 Emission Levels with Original FHWA Levels, Reference (2)



(a) HEAVY TRUCKS

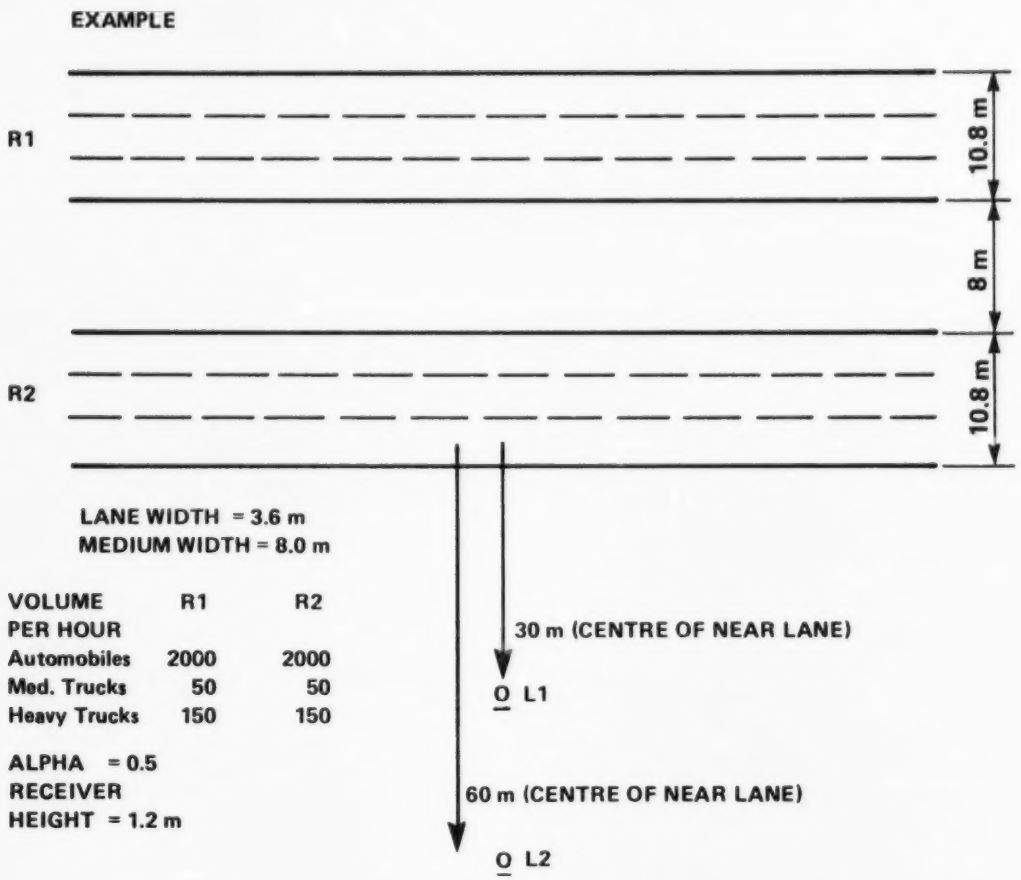


(b) MEDIUM TRUCKS



(c) AUTOMOBILES

Figure 10/ Standard Deviations of Emission Level Curves



RESULTS	FHWA DATA (dBA)	ONTARIO DATA (dBA)	DIFF. (dBA)
L1	73.9	73.0	0.9
L2	70.1	69.3	0.8

Figure 11/ Comparison of the Effect of New Ontario Emission Levels with Original FHWA Levels, for FHWA Classification

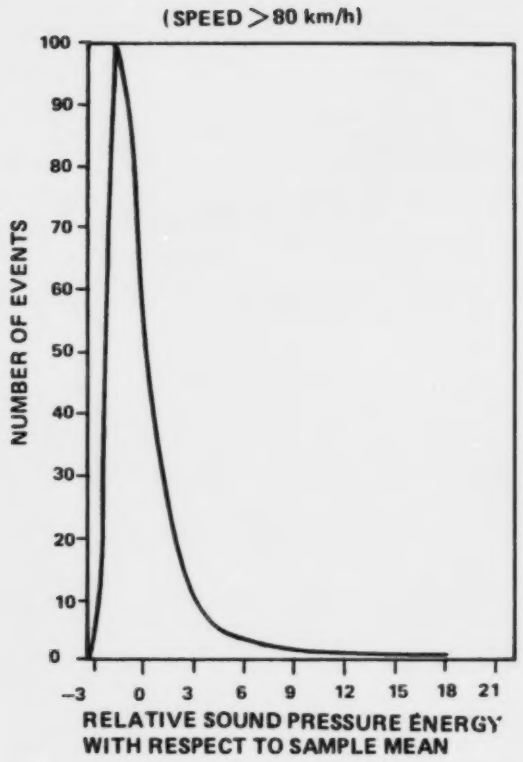


Figure 12a/ Heavy Truck Noise Distribution

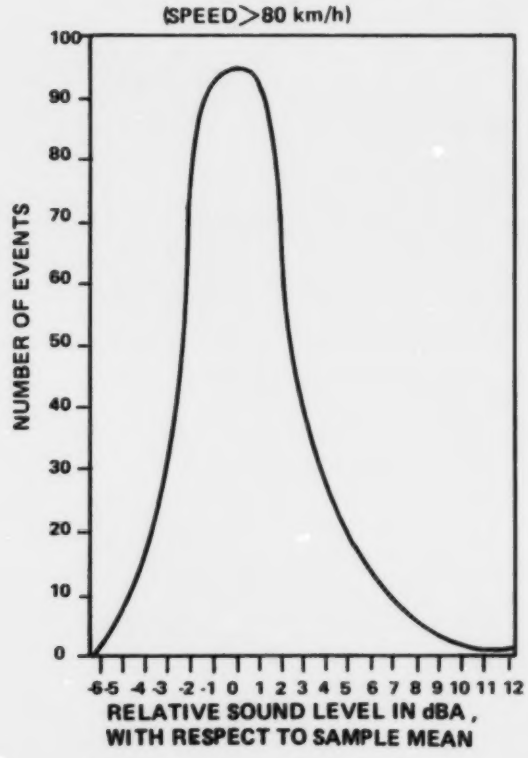


Figure 12b/ Heavy Truck Noise Distribution